

**Resilient Organisations
Research Report – 2006/02**

Information Sharing During Disaster

Can we do it better?

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Resilient Organisations

The Resilient Organisations research programme aims to improve the resilience of New Zealand organisations to major hazard events. Organisations manage, maintain and operate our infrastructure, create our economy and contribute to our society. The ability of organisations to respond effectively following a hazard event will have a large influence on the length of time that essential services are unavailable, and ultimately how well our communities cope with major disaster.

Particular aspects of organisational response and recovery focused on by the research team include: how organisations plan for hazard events, their ability to direct resources effectively during crises, and the legal and contractual frameworks within which they will need to operate.

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Executive Summary

This report presents a critical review and analysis of issues involved in implementing electronic data and information sharing frameworks for organisations involved in emergency response and recovery activities. Response to major emergencies involves multiple organisations collecting, collating and communicating data and information to enable better decision making that minimises social and economic impacts. The challenges involved in co-ordinating an effective response to large scale events are compounded by the number and variety of organisations involved. These complexities emphasise the need to develop robust yet simple frameworks for sharing information and communicating decisions within and between organisations involved in response and recovery activities.

This report specifically focuses on organisations involved in response and recovery activities for the State Highway network during times of emergency, and how information sharing between these organisations might be streamlined to improve the effectiveness of that response and recovery. The first section of the report reviews the New Zealand emergency management context, and those organisations involved in emergency response for the State Highway network in particular. The report then describes a case study emergency event in Matata, where the interactions between organisations involved in restoring the road network were observed to better understand how response and recovery decisions are made, and the realities of information sharing during crisis.

The report then reviews opportunities for improving communications and proposes a new framework for data and information sharing within and between organisations involved in response and recovery for the State Highway network. The framework proposed utilises Transit NZ's current inventory database (RAMM) to generate a Dynamic Geographical Information System (DGIS) for emergency response. A Dynamic GIS differs from a traditional GIS system in that it has the capability to incorporate, display and share information continuously.

The report also discusses challenges to implementing such a framework and the potential implications for organisations involved. In particular it highlights that there are significant challenges to encouraging enhanced communication and data/information sharing, particularly given that most communications interoperability issues are not technical in nature. Organisational cultures, differences in terminologies, and incompatibility of standard operating procedures all create barriers for progress. However, perceived barriers can be reduced if technology is employed according to an organisation's needs rather than the other way around.

During design of the proposed DGIS framework significant focus was placed on the nature and background of involved organisations; the characteristics of their involvement in response and recovery activities; their data/information needs; their data/information sharing needs; and how organisations could/should share data and information. It is hoped that by involving end-users during all development stages of the electronic data and information sharing framework, that researchers and end-users together, can develop an effective framework that complements the organisational structures, cultures and existing interfaces between the organisations involved.

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1. Introduction

The New Zealand State Highway network is a vital lifeline for communities, providing access for people, goods and services around the country. In times of disaster, the roading network becomes particularly important as a means of evacuation for getting into and out of the disaster zone, and also as a means into a disaster zone for emergency services, and supplies needed to restore and rebuild communities. As highlighted in Risks and Realities ^[51], the roading network actually is one of the most critical lifeline services, as without road access, many of the other lifeline services (such as water, electricity, telecommunications etc.) cannot access their sites to effect repairs. All of this points towards the need to have a road network that is resilient in the face of disaster.

Resilience of the roading network has two aspects: the vulnerability of the road network to disruption during disaster, and the time it takes for the road network to be restored following disaster. This report primarily focuses on this second aspect of resilience, the speed and efficiency with which the road network is restored following major disaster.

Restoration of the road network requires multiple organisations to work together, most likely in conditions of high personal and organisational stress, significant uncertainty as to the extent of the damage, limited communications, with key staff members unavailable, and without access to normal support services such as fully effective IT systems or even potentially hard-copy files if offices are inaccessible. It is therefore as much an organisational challenge to restore road transport services, as a technical or construction issue.

This report explores communication channels between the organisations involved in response and recovery activities for the State Highway network during times of emergency, and how these communication channels might be streamlined to improve the effectiveness of that response and recovery. The first section of the report reviews the New Zealand emergency management context, and those organisations involved in emergency response for the State Highway network in particular. The report then describes a case study emergency event in Matata, where the interactions between organisations involved in restoring the road network were observed. The report then reviews opportunities for improving these communication channels and proposes a new framework for data and information sharing within and between these organisations during times of crisis. The report also discusses challenges to implementing such a framework and the potential implications for organisations involved.

It should be noted that this framework specifically focuses on information sharing between organisations in the response and recovery of the State Highway network. Although it is recognised that the methodology will eventually need to cover organisations managing the entire road network, the number of different Councils involved in managing local roads significantly increases the complexity involved in understanding and modelling the information management structures required. For that reason, this study focuses only on the State Highway network, but the methodology employed could later be extended to the full road network if desired. Even though State Highways (SH) make up only a small portion of New Zealand's total road network, they are very important because traffic flows are much higher on SHs than on local roads.

2. Current Practice and Issues in Disaster Response

2.1 Emergency management in New Zealand

In New Zealand, the Ministry of Civil Defence and Emergency Management (MCDEM) is a semi-autonomous body within the Department of Internal Affairs. MCDEM has over-arching responsibility for developing and maintaining the preparedness of the New Zealand community for any natural and technological hazards or disasters [1]. Created in 1999 from the former Ministry of Civil Defence, MCDEM also provides policy advice to the Government [43].

In 2002, the Civil Defence Emergency Management Act established a national and regional framework in which an emergency management strategy and plan were adopted. One of the features of the Act is the establishment of CDEM Groups based on regional council boundaries, and the requirement that a risk management-based approach be adopted. CDEM Groups are consortia of local authorities, emergency services and health boards in each region.

The CDEM Act (2002) requires every local authority to plan and provide for Civil Defence and Emergency Management (CDEM) within its district, and to ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency. One of the features of the Act is that this requirement also applies to lifeline utilities and central government departments. MCDEM works in coordination with local and regional governments, utilities and the emergency services involved in CDEM. MCDEM's Director acts as Chief Executive of the Ministry in its day-to-day operations. In cases of national emergencies, the Director has special powers defined in the legislation.

In the event of a Civil Defence Emergency declaration, the CDEM Group (or local) Civil Defence Controller co-ordinates the response and makes decisions about key response actions after communication and consultation with the emergency services, health agencies and key lifeline organisations. The regional and national CDEM Emergency Operations Centres (EOCs) interact with these organisations to facilitate and support decisions on prioritisation of response activities. Relevant data/information from all the above organisations is expected to be shared with CDEM agencies to facilitate decision making.

2.2 Interaction between CDEM Agencies and Transit NZ

New Zealand has about 10 thousand kilometres of State Highway network. These roads are a national asset worth approximately NZ\$12 billion and Transit NZ is responsible for maintaining and enhancing these assets. 56% of the annual budget is allocated for the maintenance and rehabilitation of existing roads.

Typically, Transit NZ appoints Consultants to undertake technical services to determine work requirements according to Transit NZ Regional office's directives, and Contractors for carrying out the physical works [44]. The State Highway network is divided into seven regions, each with their own Consultant and Contractor arrangements.

This structure provides the State Highway network with some resilience during emergencies in that many of these Consultants and Contractors are national or sometimes even international organisations. This means that resources can be brought in from other areas to boost resources available to an affected region during the crisis. However this structure also adds complexity that

needs to be recognised and managed. As the number of organisations involved in effecting response and recovery increases, particularly if an emergency spans more than one region, communication and sharing of information within and between organisations becomes more complex to manage.

During an emergency situation it is the responsibility of the Contractor to carry out the physical repairs and reopen the road to the traffic as soon as possible. The Consultants provide oversight and technical advice to the Contractors. The Consultants also interact with representatives of Transit NZ, and where appropriate, CDEM agencies. This structure, whereby Transit NZ, the Consultant and Contractor (and where appropriate CDEM agencies) all need to work together and share information to inform real-time decision-making in response to events, provides an excellent case-study for developing a data/information sharing framework.

Emergency situations are classified by Transit NZ into 3 levels according to the time required for road reopening: small (a specific part/segment of the State Highway network is affected for an approximate duration less than 6 hours), medium (multiple parts/segments of the State Highway network are affected for up to a day) and large events (severe damage to the State Highway Network, other lifeline infrastructure systems and life treating situations are observed, prompting Civil Defence to dictate response and recovery priorities). Based on emergency procedure manuals ^[44], Table 1 summarises the roles Transit NZ and CDEM agencies play for these different events.

Table 1. Transit NZ and CDEM participation for different types of events.

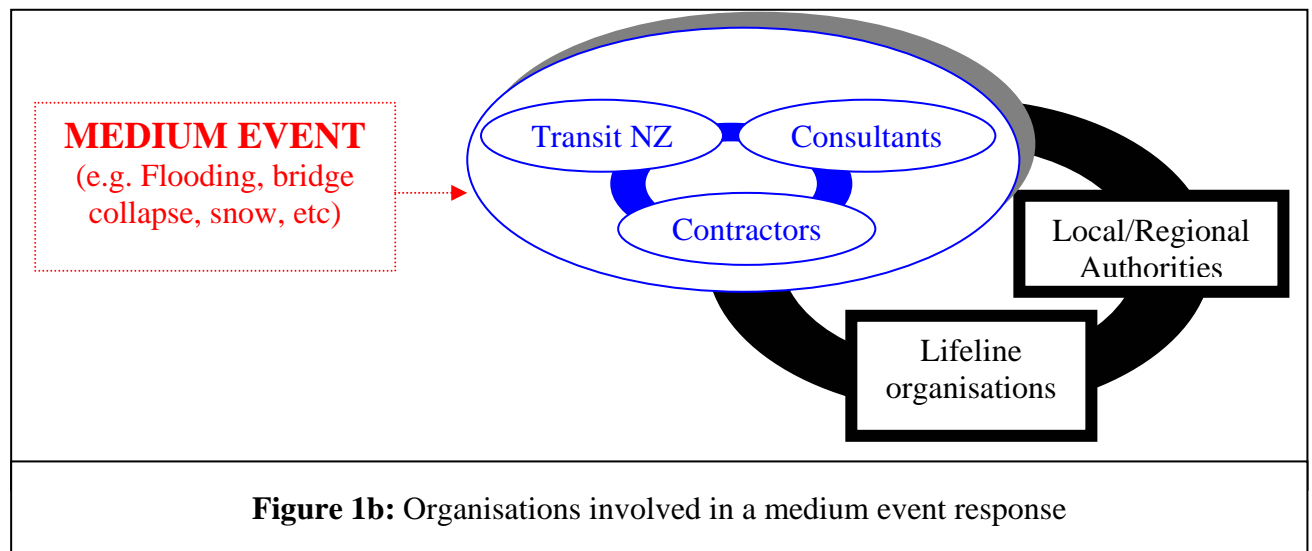
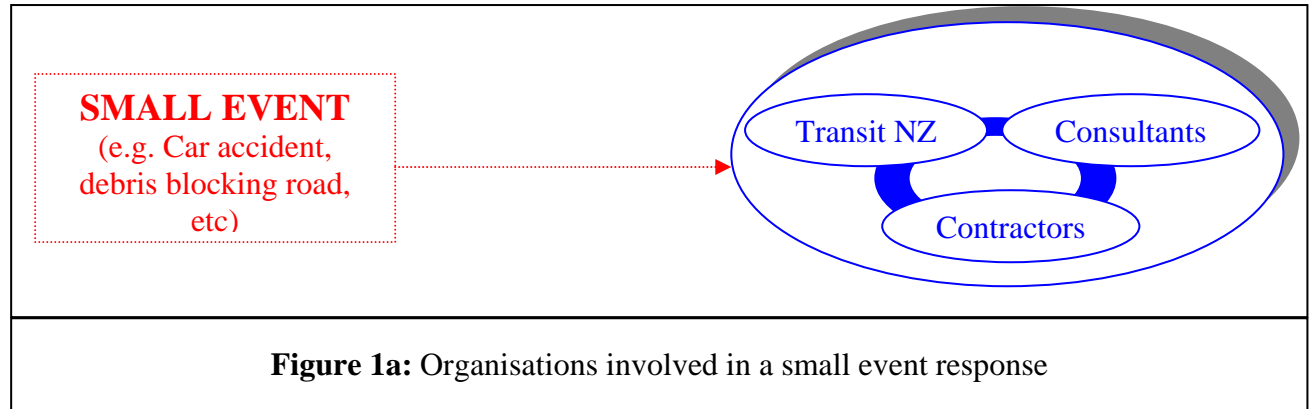
		Type of Emergency		
		Small	Medium	Large
Organisation	Transit NZ	Stand-by unless the emergency affects SH system	SH Emergency Procedure and Contingency Plan fully applied.	SH Emergency Procedure and Contingency Plan are partially applied. Define response priorities for the SH network.
	CDEM Agencies	N/A	- Local EOC /CDEM groups play a monitoring role; and - NCMC is kept informed about event characteristics	Civil Defence Emergency declared. Local, Regional or National Civil Defence Controller defines overarching response priorities and has the ability to direct resources if necessary

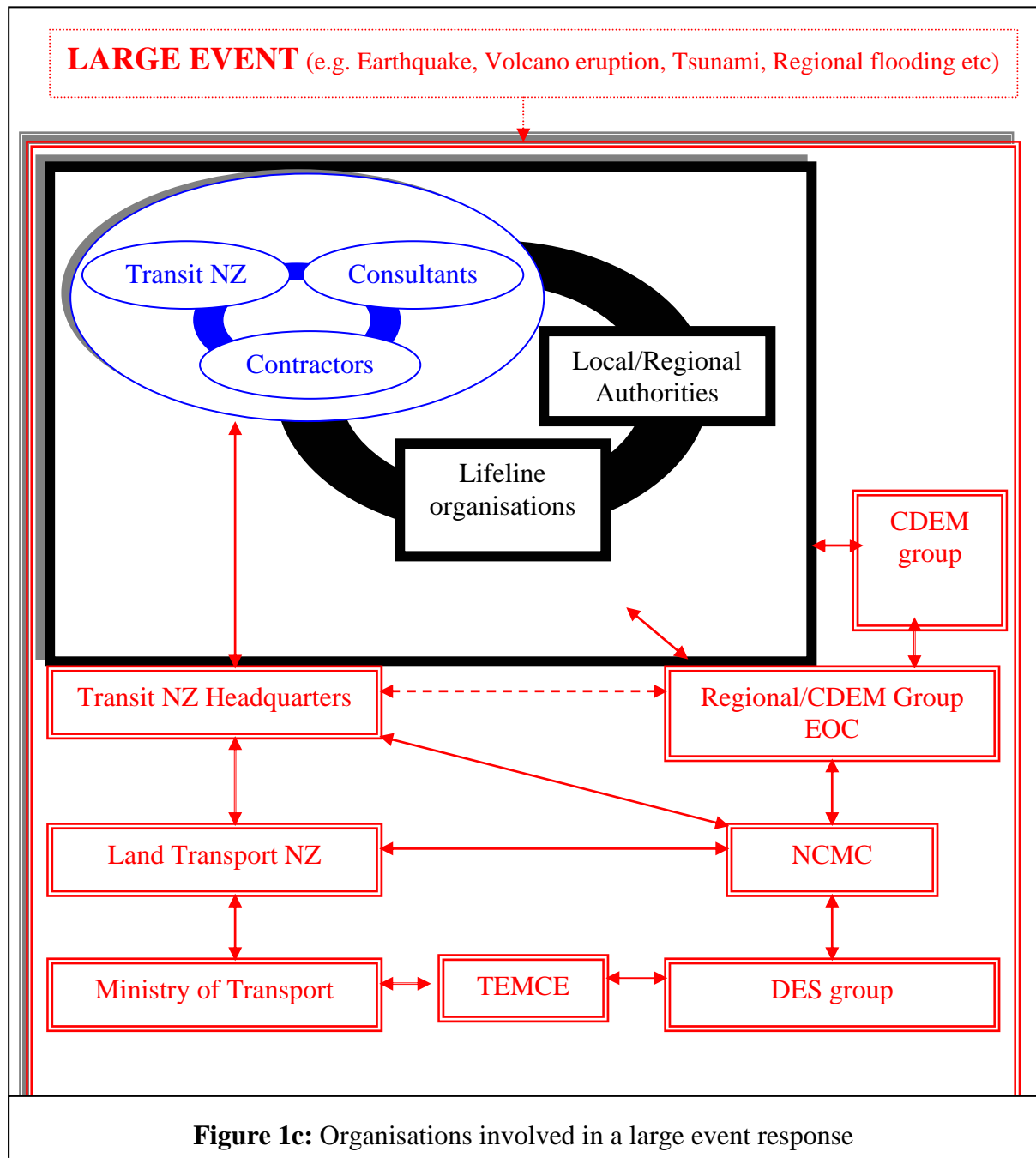
A large event refers to a situation in which severe damage is observed and CDEM agencies may influence the priorities for response and recovery activities to reflect specific community needs. When a civil defence emergency is declared during a large event, Transit NZ needs to work in co-ordination with CDEM agencies. Transit NZ headquarters in Wellington is also involved in a large event and it reports to Land Transport NZ and the Ministry of Transport (MOT). In these situations, Transit NZ also interacts with the community through individuals, external organisations such as telecommunications, energy, water, hospitals and the media etc.

Figures 1a, 1b and 1c show a representation of the organisations involved in different scaled events. The challenges involved in co-ordinating an effective response to a large scale event are compounded by the number and variety of organisations involved.

Organisations involved in response and recovery activities need a large variety of information. In order to act in a coordinated and effective way organisations require access to data and information characterising the disaster's intensity, location and related damage, as well as the availability of human and physical resources. Organisations will have their own particular information needs, which may be different for each level in the organisation. For example, Transit NZ Headquarters' personnel in

Wellington will need general road closure information such as summary of damage, expected opening, forecasted recovery cost, etc. On the other hand, the Transit NZ network engineer will need access to much more specific information about damage, work progress, costs and resources availability. Based upon the available information, both sections will make their decisions on allocating the resources over time and space.



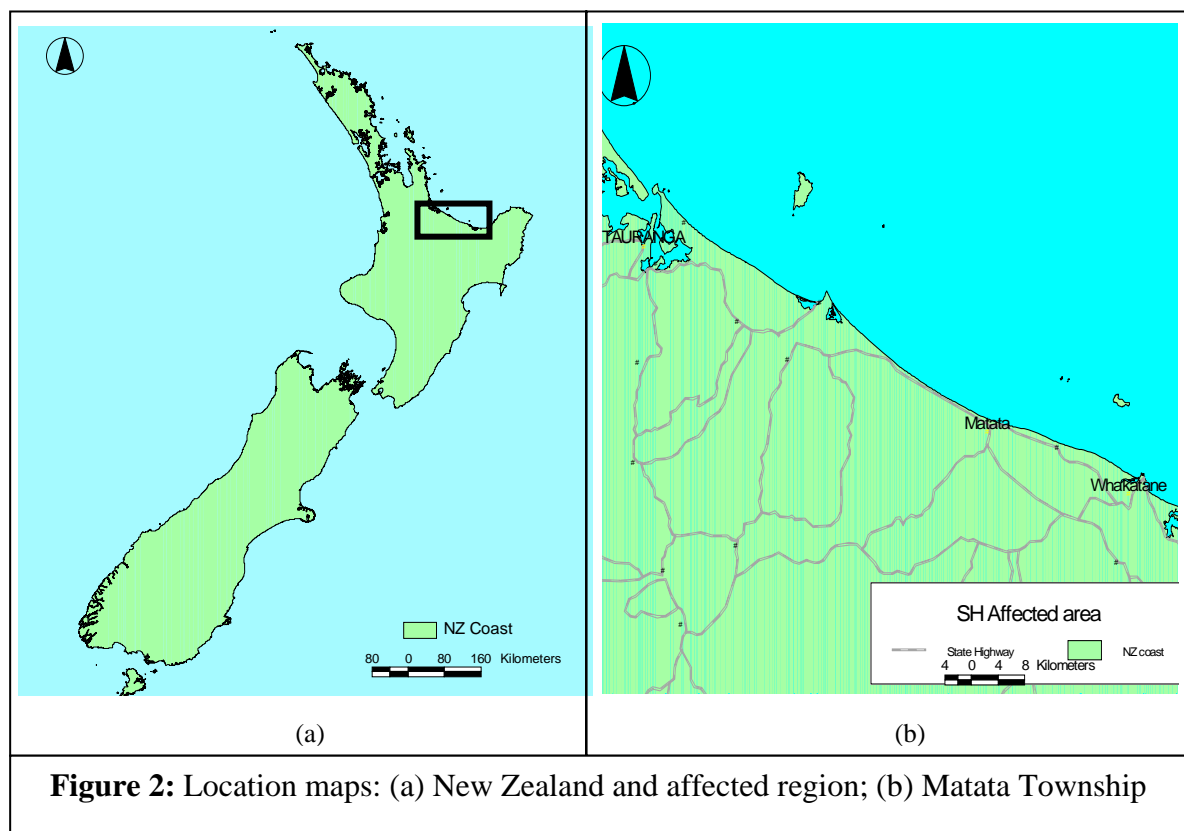


3. Case Study: Organisational Response Observed in Matata

In order to better understand how response and recovery decisions are made, and the realities of information sharing issues during crisis event, the research team sought permission to act as ‘fly on the wall’ observers during the flooding and debris flow events around Matata in May 2005.

After initial TV news reports of the Matata events evolving, members of the research team contacted the regional office of Transit NZ in Hamilton about the event to establish *in situ* interaction with the involved parties and obtain permission to observe the response activities in Matata. The remainder of this sub-section is based on *in situ* interviews and examination during two visits (May 20 and May 26/27) to the damaged area.

Matata is a seaside village of approximately 500 people in the Bay of Plenty region, North Island of New Zealand as shown in Figure 2. Matata is located halfway between Whakatane, which is a forestry industry region, and Tauranga, where one of the busiest ports of New Zealand is located. Whakatane and Tauranga are connected by railway and road, with the State Highway (SH) 2 being the most important part of the network, with heavy traffic observed daily in both directions.



The 2005 Matata township flooding was a small-medium emergency event in which practical issues in data/information sharing among roading organisations were observed. In contrast to previous year's events that caused widespread damage in the Bay of Plenty, the 2005 event was confined mostly in the Matata township and its nearby coastal area, which comprises a portion of SH 2 known as the “Matata Straight” (approximately 5 km of road). As emergency response was concentrated in very specific parts of the roading infrastructure, involved organisations and their resources were coordinated locally by the Transit NZ area engineer and Consultant.

3.1 Event Chronology

On the evening of May 16, 2005, MetService issued a heavy rain warning to the local (Whakatane District Council) and regional authorities (Bay of Plenty Regional Council). They also notified all infrastructure and lifeline providers in the region, including Transit NZ offices in Hamilton and Gisborne.

In the early hours of May 17, the Transit NZ area engineer and the Consultant engineer, who were coincidentally meeting together in Whakatane, received initial reports from the local community and Transit NZ Contractors about partial road closures on SH 2 due to water on the road surface and localized slips blocking traffic (See Figures 3, 4 and 5). The fact that both the Contractor and Consultant representatives were together at the time the event escalated, simplified subsequent communications significantly and allowed for shared decision making.



Figure 3: Matata Straight. Trucks stranded between Hauone and Pikowai Bridges as of 10:00hrs, 18/05/2005 (Source: Transit NZ – Hamilton Office)



Figure 4: Hauone Bridge SH 2 RP 209/3.040 - Photo taken at 10:00hrs 18th May 2005. (Source: Transit NZ – Hamilton Office)



Figure 5: Pikowai Bridge SH 2 RP 209/3.040 - Photo taken at 10:00hrs 18th May 2005. (Source: Transit NZ – Hamilton Office)

An additional contracting crew was mobilized to the location of the road closure from various parts of the region via mobile phone. SH2 was reopened approximately 12 hours after the first warnings were received. The poor weather conditions continued overnight however and during road inspections the following day (May 18) the Transit NZ area engineer and Consultant engineer together, actually witnessed the washout of one bridge embankment.

Subsequent reports from road users about more washouts prompted the Transit NZ area engineer and the Consultant engineer to hire a helicopter in Whakatane and conduct a fly-over inspection. Immediately after the inspection, complete road closure of SH 2 was declared and supplementary personnel and equipment from the Transit NZ Contractor were requested.

Up to that point in time, communications and exchange/sharing of data and information were very limited. Transit NZ Headquarters in Wellington had been informed of the road closure, without any precise estimation of the reopening time. The area engineer liaised with local and regional councils sharing the same level of information available to Transit NZ Headquarters. Press releases were given to the media about the road closures (Appendix A shows a media release that describes the roading conditions on May 23). Interaction between the Transit NZ area engineer and the Consultant engineer occurred almost instantly as both were *in situ* coordinating and making decisions together.

The Consultant engineer, originally based in Matata, reported back to his office in Whakatane via mobile phone communications and using his deputy road technician. Consultant's reports were used to produce maps of road closures and initial estimates of damage and costs (Appendix B shows a road closure map produced by the Consultant on May 23). Transmitted data comprised very general instructions referring to road assets per kilometre. No specific data on previous road asset conditions (e.g. location and characteristics of roading elements) were readily accessible to the involved parties (Transit NZ, Consultant and Contractors).



Figure 6: Matata Township – Coast to land view, early hours of May 19, 2005 (Source: Transit NZ, Hamilton)

On the afternoon of May 18, a Civil Defence Emergency was declared by the Western Bay of Plenty Emergency Management Office. Subsequently the Whakatane District Council also declared a state of local emergency for the Edgecumbe-Tarawera Ward (Matata township) on the evening of the same day (May 18) (See Figures 6 and 7). Late that night, a band of intense rain passed over the catchments behind Matata and triggered many landslips (debris avalanche), which destroyed 27 homes and seriously damaged 87 properties ^[45].



Figure 7: Matata Township, early hours of May 19, 2005 (Source: Transit NZ, Hamilton Office)

Initial response actions commenced immediately. Resources were already available in the area for dealing with the earlier road closures. However, a major drawback was a lack of suitable gear for operating during the night because batteries for the spotlights available were faulty. Communications relied almost entirely on cellular mobile telephones and radio telephones (RT's). All involved parties (Transit NZ engineer, Consultant and Contractor) were using Telecom cell phones, which had good coverage in the area. Conversely, the research team had some difficulties contacting the response parties, because our Vodafone cell phone had very poor coverage in some areas of the affected region. Radio communication was largely used between the contractor's crew. Localised communications over short distances, such as for the direction of machinery and personnel were very well suited to low frequency RT communications. Nevertheless, during times of confusion, face-to-face communications proved to be the most effective means of getting activities underway.

The landslips in Matata and complete closure of SH 2 created difficulties in transporting equipment and personnel from Tauranga in order to effect repairs (See Figure 8). Alternative routes through mountainous areas had to be used, which incurred delays in the response actions. Nevertheless, the contractor mobilised a considerable number of personnel (over 50 people) and machinery (25 heavy load trucks, 10 diggers, 4 bulldozers, 1 grader, etc).



Figure 8: Transit NZ deployment of resources in Matata, May 20, 2005 (Source: Transit NZ – Hamilton Office)

On May 20th SH 2 partially reopened overnight (5pm to 5am) for use by heavy and commercial traffic only (see Figures 9, 10 and 11). On May 30th, 14 days after the initial closures, SH 2 was completely reopened to general traffic. At that point in time, Transit NZ had no specific assessment of road repair costs, but approximate estimates ranged from 2.5 to 5 million dollars. Daily information on damage and resource deployment was recorded by the consultants. It consisted mainly of a list of damaged assets, their priorities and recommended treatment. This information was shared with the contractor using paper.



Figure 9: Transit NZ partial re-opening of SH 2 May 20, 2005



Figure 10: Transit NZ deployment of resources in Matata, May 20, 2005



Figure 11: Transit NZ deployment of resources

3.2 Organisational coordination and data/information sharing during the event

During the response activities, members from the research team observed interactions between Transit NZ, Consultants and Contractors. In comparison with previous hazard events (such as the 2004 flooding in the Manuwatu-Wanganui region ^[42]), flooding and damage in this instance were much more localised. This simplified the allocation of resources somewhat. The prioritization process

consisted of visual inspection by the Consultant technician and the Contractor representative. Together they listed assets and decided on a ranking and treatment options, without explicitly considering the previous state of the assets or the costs of repairs.

The Transit NZ Consultant noted that there would be clear gains in efficiency if Contractors knew the exact location and prior characteristics of the roading elements such as signage, culverts, etc. This mainly reflects the limitations of the Road Assessment Maintenance Management (RAMM) information database employed in Transit NZ daily operations. Ironically, Contractors and Consultants managed to download television reports about the events from the internet using their mobile phones, but they were unable to determine what was underneath the mud.

Observation of communications and data/information exchange/sharing during the Matata events indicates that informal linkages and assessment were the dominant form. Involved roading organisations depended heavily on individuals' previous knowledge about the area and assets. Obviously, previous knowledge was very important, but there are concerns about how efficiently it can be employed on its own to solve more complex problems such as would be the case in a larger scale event. Moreover, "common sense" compensating a lack of information was constantly employed.

On the other hand, the current information system (RAMM) was perceived as not suitable for coping with the dynamic nature of such an event. This has probably forced Transit NZ, the Contractors and Consultants to respond as observed. RAMM is largely employed in asset management and maintenance of State Highways, therefore it is programmed and organised to support medium term decision-making. It gathers road asset information on a kilometre length basis. Each highway is divided into multiple segments, which are subdivided into kilometre units, to which all roading elements (post signs, culverts, drainage elements, pavement, etc) are referred to. Nevertheless, during an emergency event, kilometre based reference to roading assets has very limited information value, because damage may have altered the whole arrangement and location of roading elements. For example, the contractor may want to replace a stop sign using RAMM-kilometre reference, but the road alignment has been completely changed due to mud and debris and it becomes impossible to identify sign posts and any other references required to perform the original task. One other example indicating RAMM's deficiency in supporting emergency decision making is that during the observed deployment heavy machinery no data was retrieved from RAMM in order to indicate, for instance, original grading and alignment.

Another issue observed during the case study was the potential fragility in a larger scale event of the communication systems used to manage the response. The predominant means of communication between the Transit New Zealand engineer, the Consultant and the Contractor was via either face to face meetings or by cellular/mobile telephones. The RT network was used also for communications during the response; however it was only used for communications between members of the same organisation. In a large scale emergency event the cellular/mobile phone network is likely to be an unreliable means of communication; cell phone towers may be damaged, there may be poor network coverage at the site; or the network may become simply overloaded as the volume of calls made by the general public escalates during times of crisis. The development of any emergency communications framework will need to consider how reliable voice communications between the responding organisations can be facilitated.

There are significant opportunities for improving the way that information on road status is shared during an emergency. Appendix B shows an example map of road network status that was produced during the Matata event. Standardising and setting up pre-formatted templates for such maps would not only save time and effort during an event but would also enhance the usability of the information on the maps. For example, in any map of this kind, cartographic standards should always be applied including the use of scales, referencing the map to clearly identify where the mapped area is located, and the use of standardised symbols to avoid misinterpretation. Visual strategies should be developed where possible to convey information so that the need for text commentary is minimised.

As highlighted by Peter Wood^[50] emergency management requires information to be visualised so that it can be interpreted quickly, easily and consistently across the different organisations involved in response. This requires integration of and interoperability between datasets, including the use of common standards and symbols, compatible reference frames, and protocols for sharing and protecting data and information.

Overall, management of the response and recovery observed from the Matata event was very effective. The people on the ground knew each other very well, and this helped to facilitate shared decision making and communications. In a larger scale event however, those managing the response and recovery may not know each other so well, particularly where external people are brought into the area to support local teams. In a larger scale event, where more organisations are involved and the situation is more complex, there is likely to be a need for more formal structures for planning and co-ordination.

4. Opportunities for Improving Information Sharing

As part of this research, an international literature search has been undertaken to seek out international best practice and innovations for information sharing between organisations to enhance coordinated decision making in times of crisis. International research on intra- and inter-organisational issues in emergency response is typically concentrated on three main topics, namely:

- organisational coordination;
- emergent technologies and techniques in data/information processing;
- evacuation planning.

The following subsections summarise the key findings from that literature review.

4.1 Organisational coordination

Organisational co-ordination refers to the ways that organisations work together, sharing information and contributing to integrated decision making to achieve a common goal. The main themes found in the literature regarding organisational co-ordination during emergencies are as follows.

- **Lack of coordination reduces response efficiency.** Various international reports of recent events in the USA, Costa Rica, Turkey and Canada show that bringing together organisations and making them working together is crucial in saving lives and reducing disruption. These studies point out that organisations struggle during response activities, because most problems are originally related to urban and regional planning and cultural differences between organisations, i.e., coordination is not only about operational issues (who/how does what) but also about preparation before the event.^{[1] [2] [3] [5] [6] [7]} Organisations that have established a culture of working together in developing their response plans are more likely to work effectively together during a crisis event. Not only will their response plans be better integrated, but the principles and ethos that these organisations bring to the response are also likely to be better aligned.
- **Growing concern over the need to obtain and share data during emergency events.** Organisations responding to an emergency event have to make difficult decisions about personnel and equipment deployment. The accuracy and reliability of these decisions obviously depend on the quality and availability of information (e.g. a roading consultant deciding whether to close a bridge or not, based upon reports from the public). The scientific reports indicate that sometimes organisations have access to all sorts of information. However, they also demonstrate that abundance of information does not necessarily mean useful information (e.g. having all the structural details of all bridges and not knowing the traffic flow on them will not help in assessing the closure or not of a specific bridge). Many organisations have expressed the view that data and information management is critical for performing their activities and that access to more and better quality data, as well as having the means to share that data with others, is essential for improving the effectiveness of their response.^{[8] [9] [10] [11] [12]}

4.2 Emergent technologies and techniques in data/information processing

Many organisations are already taking advantage of significant advances in various technological areas such as telecommunications and geo-information technologies. The main themes found in the literature regarding emergent technologies and techniques are as follows.

- **Tools such as Geographical Information Systems (GIS), Global Position Systems (GPS) and Remote Sensing are already part of the emergency management and response reality in various countries.** Mostly, these tools have been used in before and after assessment of disasters, as well as decision-making processes, risk and vulnerability assets, network operations and traffic management. Many reports claim that without tools such as GIS quick evaluation of immediate response needs would not be possible, because damage are usually observed in large areas and of difficult access^{[13] [14] [15] [16] [17] [18] [19] [20] [21] [22]}.
- **The real potential of tools such as GIS, GPS and Remote Sensing has been properly used yet.** Most commercial desktop software is inefficient in representing the complex characteristics of response systems. For example, GIS databases are often employed in order to present damage in disaster affected areas and discuss preliminary response actions. However, they are almost useless for *in situ* deployment of resources because they do not represent in detail what the final data end-users require for repairing damage (e.g. a GIS network map highlighting road closures is not useful to contractors that have to repair culverts, stop signs, etc). This situation becomes even more complex because some emergency response organisations purchase a GIS software without even analyzing whether or not the package will suit its needs during emergency events^{[23] [24] [15] [25]}.
- **Recent telecommunication advances are already fundamental to emergency response.** Wireless communications, internet and other integrated technologies for data exchange are now sufficiently developed to enhance response activities during disasters. Traditional short-wave radio and land-phone lines are not anymore the sole options in establishing communication links. Hybrid (combination of wireless and cellular networks) and satellite phone systems are currently operating in Japan and in the USA in order to avoid breakdowns, as observed during recent events (Kobe Earthquake and September 11 attacks in New York). Also, potential in combining telecommunication technologies to GIS, GPS and Remote Sensing tools has been reported in the scientific and technical literature. This allows on-line data sharing that would transform decision making during emergency response^{[27] [28] [29] [30] [31] [32]}.

4.3 Evacuation studies

A considerable part of the researched literature described techniques, methods and computer simulations related to evacuation of people living in damaged areas. The main findings^{[33] [34] [35] [36] [37] [38] [39]} are as follows.

- **There are a large variety of evacuation planning packages and applications** (EPlan; BTG, EXODUS, OREMS, PedGo, Assisted Evacuation Simulation, SEVEX, CyberSim, HLA, NEO, etc). They range from site analysis to large area studies in which evacuation times, casualties and resources are estimated.
- **The E-Team software package can be highlighted as a truly integrated data/information sharing tool for emergency management and evacuation matters.** However, despite its well-structured framework that allows for the participation of all involved response parties in multi-level events, one of its drawbacks is the lack of access to

multiple organisation databases and decision-support routines required for the resource allocation/optimisation.

- **Evacuation modelling efforts, especially to predict evacuation behaviour, demonstrate the value of information in improving emergency manager's decisions.** Better understanding of the characteristics of the affected population (such as wealth, levels of education, access to transport etc.) can significantly improve the ability of emergency managers to put in place appropriate measures. There are challenges, however, in that more situation specific information requires more complex modelling and it can be difficult represent human behaviour from basic rules-of-thumb or principles.

Katrina Hurricane events (2005) have prompted a large variety of research efforts in evacuation studies. For example, Fu and Wilmot^[40], Mitchell and Radawan^[41] Chiu *et al*^[42] have presented new modelling approaches to problems observed during the Katrina events.

4.4 Lessons for New Zealand

In the inter- and intra-organisational data/information sharing context, this review demonstrates that advances have been achieved, but considerable challenges ahead can be envisaged in terms of adopting knowledge and information management theory and techniques^[40].

Perhaps, the most difficult challenge is to move the focus from a technology-based approach to an organisation-oriented development of tools for helping those involved in emergency response. Many of the advances highlighted in this review have been driven by technology improvements and the desire to take advantage of the extra capabilities now available. Very limited attention has been given to conducting comprehensive analyses of the nature and background of involved organisations; the characteristics of their involvement; their data/information needs; their data/information sharing needs; and how organisations could/should share data and information. The main outcome of the technology-based approach is the development of tools that do not always meet the complex and diverse needs and requirements of emergency response organisations.

An organisational-oriented development of tools will require that all involved parties understand that technology by itself will not solve the problem. Instead, there must be an acceptance that organisations need to interact and agree on joint response standards, responsibilities and protocols as well as on how to share data/information, in order to efficiently respond to emergency events. In summary, before creating/buying any technology, organisations must assess and discuss their emergency response operation needs. Also, organisations should make sure that their technology related arrangements are in alignment with others.

These findings are in accordance with previous recommendations by New Zealand emergency management practitioners. For example, according to Neil Britton^[26] “...a key need now is making effective and efficient use of new technologies for gathering and evaluating information to best target response and relief efforts.... Nevertheless, the challenge is to ensure the means exist for sharing information across all agencies, not just in terms of the formats used but also overcoming ownership and funding issues. Central to this, however, is the need to replace a focus on organisational arrangements to a focus on resource arrangements based on potential hazard consequences...”.

5. Proposed Solutions for New Zealand

Based upon the need for efficient inter- and intra-organisational data/information sharing, a conceptual framework for achieving this is proposed. This framework was developed following the concepts of knowledge and information management ^[40].

When focusing on information sharing requirements, it is useful to consider information sources and needs during each phase of the response and recovery effort. The Transit NZ response process can be divided into 6 core elements, these are:

1. **Event warning:** Some types of hazard, such as weather related events and distant source tsunamis have potential warning times. External organisations such as Crown Research Institutes like National Institute of Water and Atmospheric Research (NIWA), Geological and Nuclear Sciences (GNS), Meteorological Services (MetService NZ), regional and local councils provide initial warning and updates of potential events;
2. **Event observation:** For some types of hazard, such as earthquakes, we do not currently have the ability to predict their occurrence. For these events, the response process starts at event observation. The Contractor along with external organisations and the public verify the initial damage caused to the transportation system (pavement and bridge collapses, obstruction of lanes, damages to traffic signs and controls, etc.). Depending on the extent of damage, these conditions are reported to the Consultants, Transit NZ, Local Road Controlling Authorities, the emergency services and other lifeline organisations, or if a Civil Defence Emergency has been declared, the regional or national CDEM EOC;
3. **Event assessment:** Depending on the type of the emergency, Transit NZ, the Consultant and Contractor, plus any supporting external organisations that can add expertise, are involved in collating information about the event and determining the best course of action;
4. **Organisation action:** This involves the same organisations deploying their physical and personnel resources according to their responsibilities for undertaking response activities. Most of the field operation is conducted by the Contractors in small and medium events. In large events the CDEM Controller, lifeline organisations and Local/Regional Authorities are also involved. These actions are supervised by the Consultant and Transit NZ;
5. **Organisation reporting:** The Contractor, CDEM, Local/Regional Authorities and lifeline organisations report on current conditions after the initial round of measures and any further development of the original event (better information about damage, more events, etc.).
6. **Organisation re-evaluation:** These reports are then taken into consideration during organisation re-evaluation, in which the organisation evaluates the measures taken and their efficiency. Finally, decisions are made as to whether to continue or stop response activities depending on the efficiency assessment. If a decision is made to continue, the process restarts again from event assessment.

The dynamic nature of emergency response is such that many elements of the response process are conducted simultaneously, and as the event develops, the appropriateness of different response strategies needs to be constantly re-evaluated.

The next step in the process identified the information needs of the organisations involved in response. This was done by examining Transit NZ's emergency procedures and reports and translating these using the Integrated DEFinition (IDEF0) modelling language (semantics and syntax) ^[48], into a summary of information needs for each organisation involved in the response. A summary of these information needs is shown in Table 2.

Table 2. Transit NZ and response partners' information needs in response activities

	Regional Consultant info needs	Regional Contractor info needs	Transit NZ Regional Office info needs	CDEM Group info needs
Event Occurrence	Notification from the Regional Contractor, Transit NZ, police, community, etc.	-Potential damaged area/region -Type of event -Intensity and expected duration -Available resources	Notification from the Regional Contractor, Regional Consultant, police, community, etc.	Notification from the Regional Contractor, Regional Contractor, Transit NZ, police, community, etc.
Event Observation	-Damaged area / region -Type of event -Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' resources -CD emergency declaration?	-Damaged area/region -Type of event -Attributes of potentially damaged assets (location; original condition; characteristics; costs; priority repair availability).	-Damaged area/region and event type -Damaged asset type; -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Initial road closure time/ costs estimation -MCDEM emergency declaration?	Notification from the Regional Contractor, Regional Contractor, Transit NZ, police, community, etc.
Event Assessment	Comparison before and after / damaged asset Location Original condition Characteristics Treatment options Costs Priority Repair availability -Contractors' available resources	Notification from the Regional Consultant informing that observed damage is being assessed.	-Report on before and after / damaged asset -Summary of damaged assets per type -Summary of treatment options -Summary of Costs/Priorities Repair availability -Consultants and contractors available resources -Initial road closure time estimation -Initial cost estimation -MCDEM emergency declaration?	-Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation
Organisation action	-Location of Contractors' equipment and personnel -Deployment times -Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Traffic management plan MCDEM emergency declaration?	-Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Deployment times -Traffic management plan -MCDEM emergency declaration?	Notification from the Regional Consultant informing the resource deployment plan and implementation progress.	Notification from the Transit NZ Regional office informing the resource deployment plan and implementation progress
Organisation reporting	Damaged area/region -Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability)	Damaged asset type Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability) -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' available resources	-Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Road closure time/costs estimation -MCDEM emergency declaration?	Notification from the Transit NZ Regional office informing the outcomes of the implementation of the resource deployment plan.
Organisation re-evaluation	-Comparison before and after / damaged asset (location; original condition; characteristics; treatment options; costs; priority; repair availability) -Contractors' available resources Stop response/Initiate Recovery mode/Continue Response?	Notification from the Regional Consultant informing that the resource deployment is being re-assessed.	-Report on before and after / damaged asset -Summary of damaged assets per type, treatment options, Costs and Priorities -Repair availability -Consultants and contractors available resources -Initial road closure time cost estimation -Stop response/Initiate Recovery mode/Continue Response? -MCDEM emergency declaration?	-Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation

Based upon the need for efficient inter and intra organisational data/information sharing, a conceptual framework for achieving this is proposed. This framework was developed following the concepts of knowledge and information management ^[40]. The first step in the process was to identify the information needs of the organisations involved in response. This was done by examining Transit NZ's emergency procedures and reports and translating these using the Integrated Definition (IDEF0) modelling language (semantics and syntax) ^[48], into a summary of information needs for each organisation involved in the response. A summary of these information needs is shown in Table 2.

These information needs were considered in the conception of the data/information sharing framework [46] that is presented in Figure 12. The framework utilizes Transit NZ's current inventory database (RAMM) to generate a Dynamic GIS (DGIS) for emergency response. In an emergency response event, the framework proposes that data from RAMM is dynamically retrieved, organized and distributed among Consultants, Contractors and Transit NZ using the DGIS. The data/information framework establishes the linkages, templates and sharing standards to enable the conversion of road maintenance data (RAMM) into information required during emergency response activities (DGIS).

For example, during an emergency event with warning (e.g. flooding), the framework (see Figure 13) is applied following the steps and the representation below.

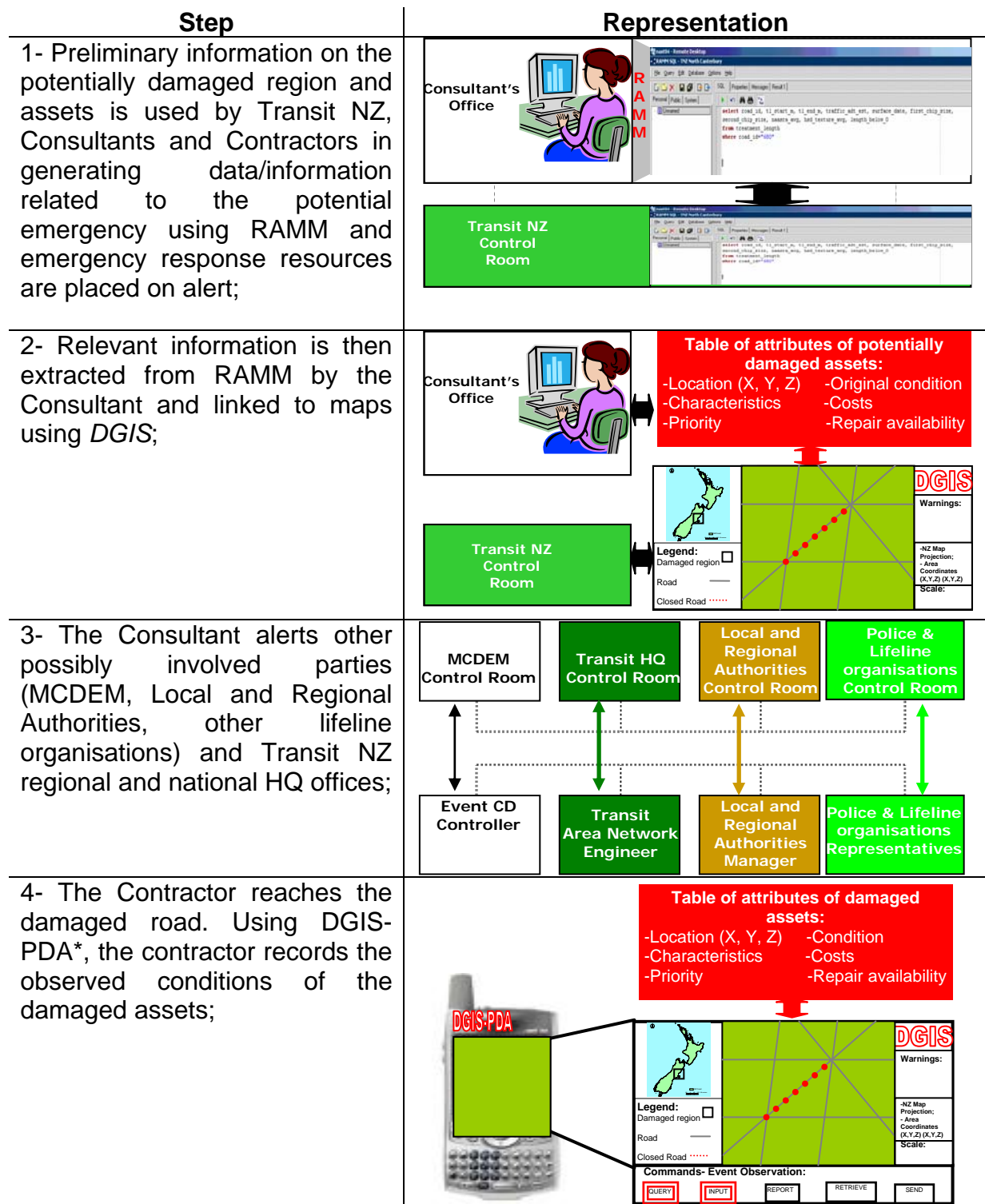


Figure 13 – An example of response steps and their representation

*PDA: Personal Digital Assistant.

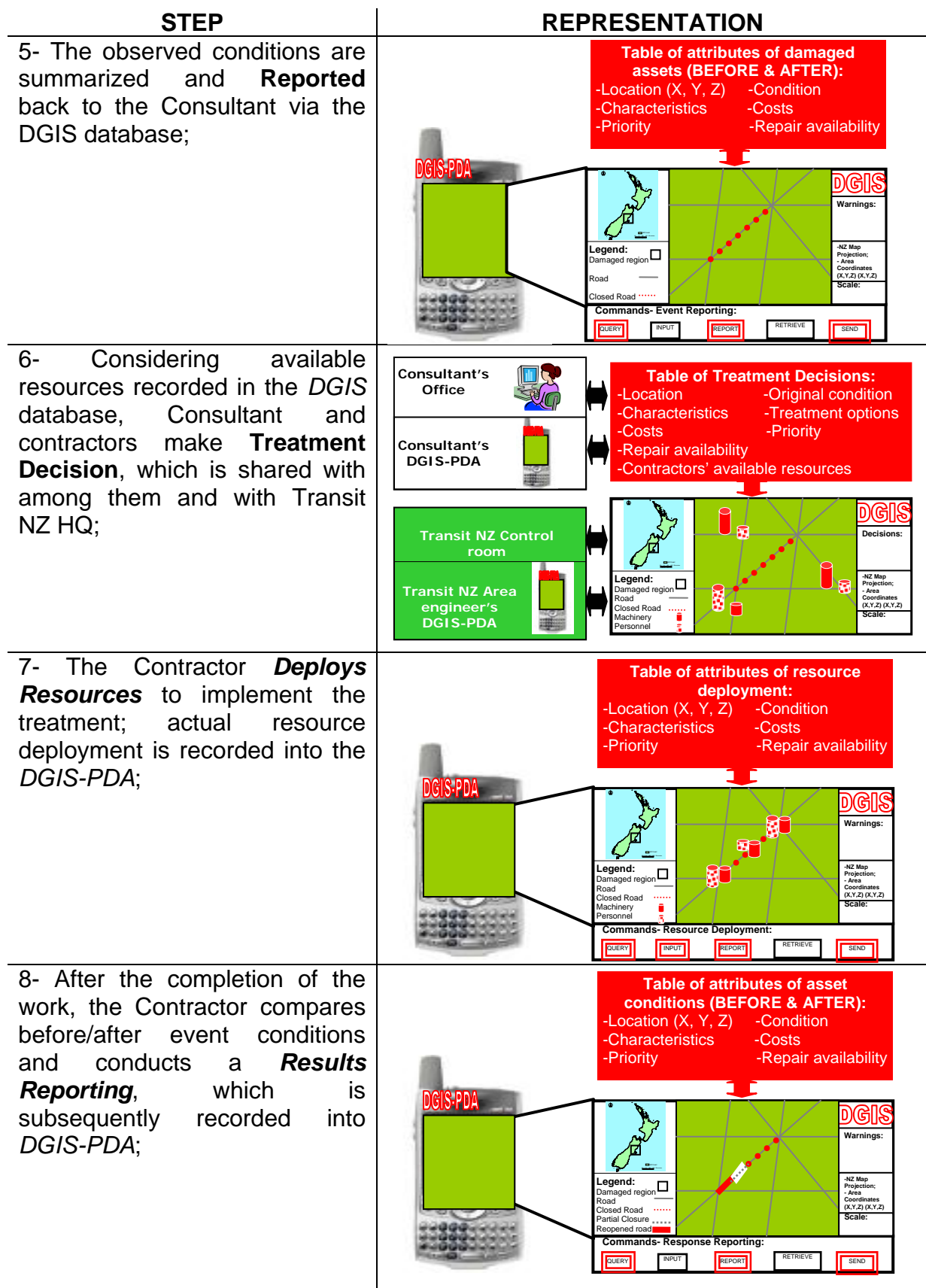


Figure 13 – An example of response steps and their representation (Continued)

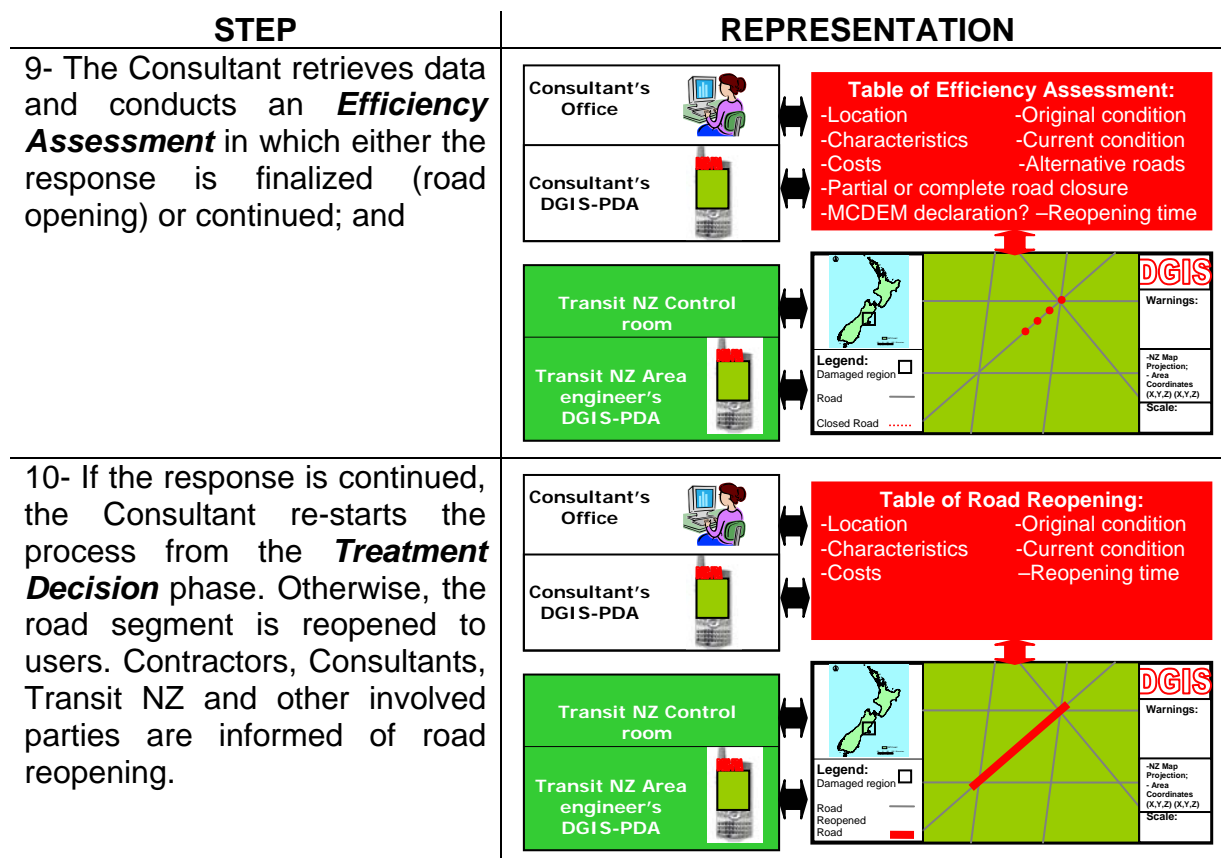


Figure 13 – An example of response steps and their representation (Continued)

Transit NZ regional engineers can either act as observers for small events or become involved with the decision making process. For events without warning (e.g. car accidents; earthquakes; etc), the same phases are followed except for the initial preparation (Emergency tables preparation and Emergency resources preparation).

During all the response phases, data is simultaneously shared with other involved organisations. The DGIS can be designed to have reports, matching pre-determined information needs, automatically collated and sent at regular intervals during the response and recovery effort. External organisations can also send information back, using predetermined formats that can be automatically uploaded and shared amongst Transit NZ's Consultants and Contractors.

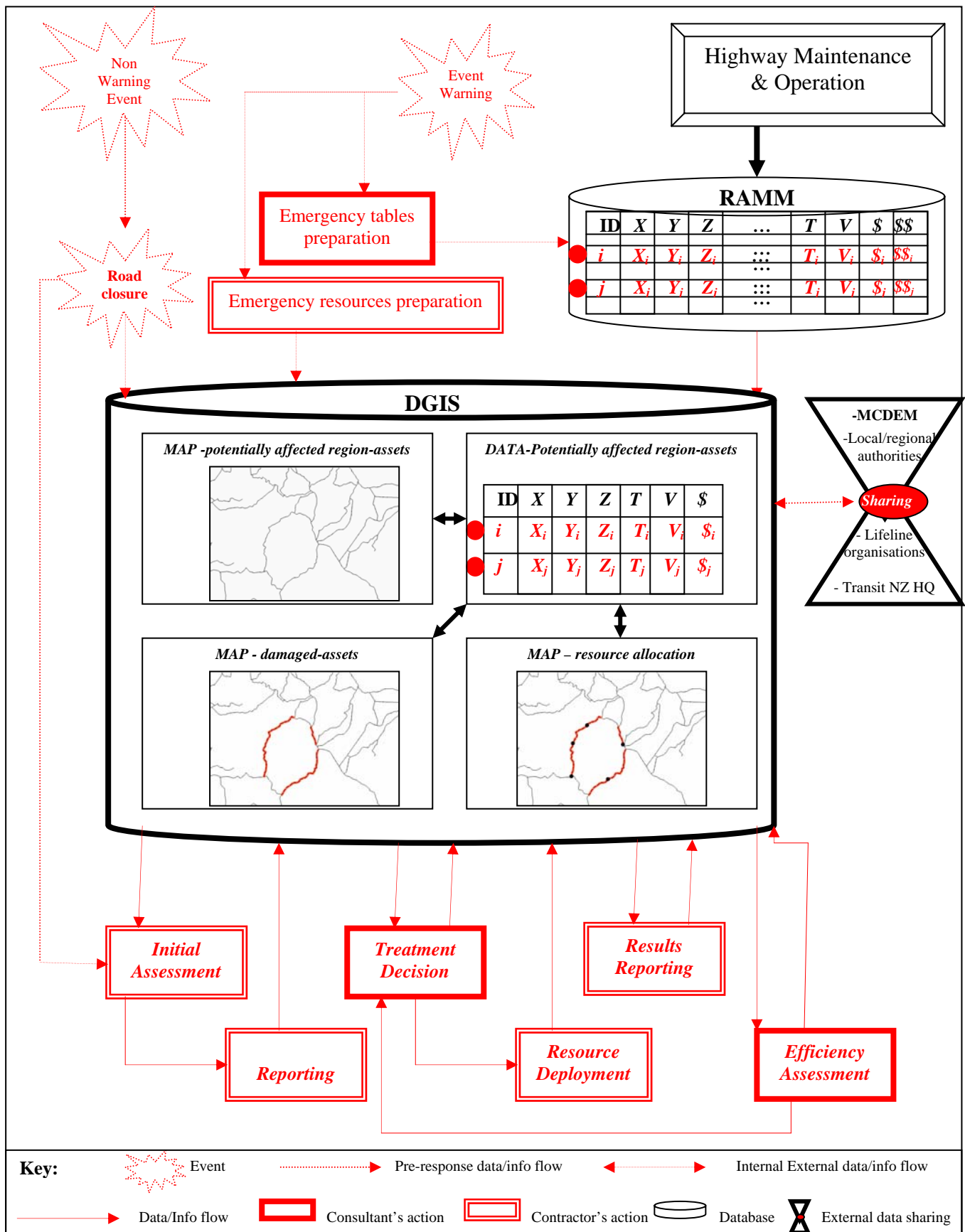


Figure 12 - Data/Information framework for roading organisations

6. Implementation Challenges and Opportunities

This proposed DGIS information framework was applied in a desktop case study in the South Island of New Zealand to establish the approximate magnitude of potential benefits. Results show that a potential reduction in time and cost of emergency response activities could be reached if the conceptual framework was implemented through reduced response times, faster access to relevant information and therefore enhanced decision making. The total cost of road closures per year in New Zealand is estimated to be approximately NZ\$2.9 million. By using the data/information framework, the road user waiting time cost of road closures could potentially be reduced by (in the best case) 5.5% (NZ\$160,000) while the worst case scenario would generate a reduction of 1.7% (NZ\$50,000) ^[46]. These road user savings were estimated by taking the recorded road closure times for historic events and breaking these down into the different phases for road closure response and recovery:

- External agency or police contact Consultants
- Consultants contract Contractors
- Contractor reach site of road closure
- Contractors inform Consultants of actual site conditions
- Decision made on repair strategy by Contractors and Consultants
- Waiting time until conditions are suitable to undertake repairs
- Complete repairs
- Contractor reporting back to Consultants.

Depending on the characteristics of the road closure event, the total road closure time was proportioned between each of these phases (for example taking into account the location of the road closure, traffic flows on the route, and the reasons for the road closure). Estimates were then made about how the response times during each of these phases might be reduced with enhanced data and information sharing technologies. This desktop case study was only a preliminary evaluation of the potential benefits of implementing a data and information sharing framework and does not consider at all the costs involved in implementing such a framework, but it clearly demonstrates that there are potentially significant savings possible through enhanced communications in emergency response.

The implementation of such a framework would require personnel training, equipment purchase (PDA or mobile phones with GPS receiver units, PC data projectors for Transit NZ control rooms), considerable commitment in changing the organisational culture and further technological and methodological advances. Both training and equipment can be justified based upon the reduction of road-user costs by reopening roads more quickly, as well as the minimisation of social and economic disruption. Nevertheless, preliminary findings not only about Transit NZ but also other New Zealand organisations indicate that there is a need for clearer understanding and communication of intra-organisational responsibilities and duties across divisional and geographical boundaries ^[47]. In particular, for the State Highway network, it is vital that Transit NZ, its Contractors and Consultants all have a shared understanding of what their roles and responsibilities will be during a large scale emergency event, and that all parties are involved in developing and testing emergency response plans.

Specific organisational issues that need to be considered in the development of the framework include the impact of different types of contract in place across the Transit NZ regions. The hybrid contract has a greater focus on Contractor autonomy in decision making, whereas the traditional contract makes greater use of Consultants. The framework will need to accommodate the potential for an emergency spanning across two regions that are operating with different contracts and have the flexibility to fit with both end-user requirements.

As for the technological and methodological advances, major disaster events require the manipulation of a large variety of data sets for national, regional, local and site specific levels. This has to be seriously taken into consideration because speed and size of each data set will certainly

influence the final data/information sharing outcome. Specific processing technology to efficiently manipulate the data sets has to be developed and implemented. The development of this technology will be the subject of ongoing research within this Resilient Organisations research programme. We aim to have a prototype of such technology developed for user testing within the next 3 years.

Fortunately, New Zealand has a solid culture of geospatial data collection and storage, which is provided by Land Information New Zealand (LINZ). Lifeline and other organisations could take advantage of LINZ's data sources and know-how in order to accelerate the development of specific tools for emergency management.

7. Conclusions

The challenges involved in co-ordinating an effective response to large scale events are compounded by the number and variety of organisations involved. These complexities emphasise the need to develop robust yet simple frameworks for sharing information and communicating decisions within and between organisations involved in response and recovery activities.

Considerable opportunities lie in exploring new paradigms for emergency response with extensive telecommunications and geo-spatial technologies. Greater focus however is needed on defining data/information sharing requirements and how the characteristics of the organisations involved affect implementation.

A major outcome of this research is that perceived barriers can be reduced if technology is employed according to an organisation's needs rather than the other way around. This is possible by involving end-users during all development stages of the electronic data and information sharing framework to develop a framework that complements the organisational structures, cultures and existing interfaces between the organisations involved.

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Appendix A – Transit NZ media release



**Hamilton Regional Office
23 May 2005**

MEDIA RELEASE

Further flooding affects highway cleanup

Further flooding at Matata, west of Whakatane, over the weekend has resulted in more debris being deposited onto State Highway 2 where it passes through the town.

Severe flooding last week deposited rocks, logs and debris across the township and washed out bridge approaches. Both the highway and railway remain closed.

The additional weekend flooding will affect timeframes for reopening the highway, Transit New Zealand advises.

Area Engineer Daya Govender said contracting staff had been making good progress clearing the highway and adjacent road reserve until heavy rain over the weekend pushed more debris onto the highway.

“The contracting team has been hard at it since daybreak today, but it is too early to predict when the highway will reopen. That decision will have to be made later this week in conjunction with Civil Defence and other agencies involved in the clean-up.”

ENDS

NEWS MEDIA: For further information, contact:

Daya Govender, Transit New Zealand, Ph 07 957 162 or 027 292 8075.

www.transit.govt.nz

Appendix B – Road Closure Maps

